Attorney's Docket No. 01997-270001 / MIT 8554

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant	: Erik R. Thoen et al.	Art Unit	: 2881
Serial No.	: 09/542,061	Examiner	: J. Menefee
Filed	: April 3, 2000		
Title	: SEMICONDUCTOR ELEMENTS FOR STABILIZING LASER OUTPUT		

Commissioner for Patents
Washington, D.C. 20231

AFFIDAVIT OF ERIK R. THOEN UNDER 37 C.F.R. § 1.131

I, Erik R. Thoen, declare as follows:

1. I am one of the inventors of U.S. Patent Application Serial No. 09/542,061, and I am familiar with the claims pending in that application.

2. I have read the Office Action mailed June 6, 2001, and the article Jiang et al., Nonlinearly Limited Saturable-Absorber Mode Locking of an Erbium Fiber Laser, Optics Letters, 24,15:1074-76 ("the Jiang article"), cited by the Examiner in the Office Action. The Jiang article was published on August 1, 1999.

3. Our pending patent application includes three independent claims directed to producing non-linear increasing loss in a passive mode-locked laser system (claims 1, 10, 26), and two independent claims directed to producing non-linear increasing loss in an actively mode-locked laser system (claims 20, 32).

CERTIFICATE OF MAILING BY FIRST CLASS MAIL

I hereby certify under 37 CFR §1.8(a) that this correspondence is being deposited with the United States Postal Service as first class mail with sufficient postage on the date indicated below and is addressed to the Commissioner for Patents, Washington, D.C. 20231.

10-4-01
Date of Deposit

Maureen Christiano
Signature

MAUREEN CHRISTIANO
Typed or Printed Name of Person Signing Certificate

4. Well before August 1, 1999, I conceived of the invention of independent claims 1, 10, 26, and reduced an embodiment to practice.

a) Well before August 1, 1999, co-inventors and I conceived a laser system with a pump, a gain medium producing radiation at an operative wavelength, and a reflector disposed along an optical path in the laser system's cavity, where the reflector includes layers of a first semiconductor material that act as a saturable absorber, and layers of a second semiconductor material that produces nonlinearly increasing loss to stabilize the mode-locked output of the laser system.

b) This conception was recorded in my lab notebook. In my notebook, I calculated that a Bragg mirror having a particular InGaAsP/InP structure and an AR coating, when placed along an optical path in a laser system producing radiation at an operative wavelength of 1540 nm, would produce non-linearly increasing TPA loss, in addition to saturable absorption. These pages from my lab notebook are attached as Exhibit A. (The date has been redacted from the notebook pages attached as Exhibit A. I represent that this redacted date is earlier than August 1, 1999.)

c) Shortly after performing the above calculations, I measured the reflectivity of the InP InGaAsP Bragg reflector described in subparagraph (b) above using a laser system producing radiation at 1530 nm, with 150 fs pulses. The data showed saturable absorption and nonlinear increasing loss. A graph depicting this data is attached as Exhibit B. (I have redacted the date of the experiment from Exhibit B. I represent that this redacted date is earlier than August 1, 1999.)

d) I believe the laser system I used in the experiment described in subparagraph (c) meets all the elements of independent claims 1 and 10. The system of my experiment included a pump, a gain medium that produced radiation at an operative wavelength, and a reflector disposed along an optical path in the laser system's cavity. The reflector included a mode-locking element (layers of InGaAsP) that acted as a saturable absorber at the operative wavelength, and a semiconductor element (layers of InP) that produced nonlinear increasing loss at the operative wavelength, to enhance the stability of the mode-locked output.

e) I also believe my performance of the experiment described in subsection (c) meets all the elements of method claim 26, for the reasons discussed above in subparagraphs (c) and (d).

5. Co-inventors and I also conceived the subject matter of independent claims 20 and 32 (directed to producing non-linear increasing loss in an actively mode-locked laser system) prior to August 1, 1999.

a) Before August 1, 1999, several of my co-inventors and I submitted an abstract to the Quantum Electronics Division of the OSA, requesting oral presentation at an Ultrafast Optics in Communications Symposium. The abstract describes using a nonlinear semiconductor mirror to suppress supermodes in a harmonically (actively) mode-locked laser system. The abstract is attached as Exhibit C. (I have redacted the date of submission of the abstract from Exhibit C. I represent that this redacted date is prior to August 1, 1999.)

b) On the same date that I submitted the abstract of subparagraph (a), I sent a letter to the New Focus Student Award Committee of the Optical Society of America. My letter describes incorporating a semiconductor element that exhibits TPA into an active harmonically mode-locked fiber laser to suppress supermodes. This letter is attached as Exhibit D. (I have redacted the date of this letter from Exhibit D. I represent that this redacted date is prior to August 1, 1999.)

c) I believe that the abstract and letter described above in subparagraphs (a) and (b) demonstrate conception of the subject matter of claims 20 and 32. The abstract and letter describe a laser system that enhances stability of an actively mode-locked output by suppression of supermodes. The system includes a pump, a gain medium, a modulator that actively mode-locks output of the laser system, and a semiconductor mirror inserted into the cavity of the system using a circulator. The semiconductor mirror produces TPA at the operative wavelength to suppress supermodes.

6. From prior to August 1, 1999, until the date the patent application was filed (April 4, 2000), my co-inventors and I worked diligently, with assistance from MIT's Technology Licensing Office and MIT's patent attorneys, to prepare and file the patent application.

a) On July 24, 1999, co-inventors and I completed a preliminary draft of our invention disclosure. (To protect attorney-client privilege, this draft is not being attached as an exhibit.)

b) On August 9, 1999, co-inventors and I completed our invention disclosure. The disclosure was signed by all inventors, and submitted to MIT's Technology Licensing Office by August 17, 1999. (To protect attorney-client privilege, the disclosure is not being attached as an exhibit.)

c) I understand that the declaration of MIT's attorney, David A. Simons, will describe the preparation and filing of the application by MIT's attorneys. As stated in Mr. Simons declaration, my co-inventors and I reviewed drafts of the application, and assisted the attorneys when assistance was requested.

7. I affirm, under penalty of perjury, that all statements made herein are true, to the best of my knowledge, information and belief.

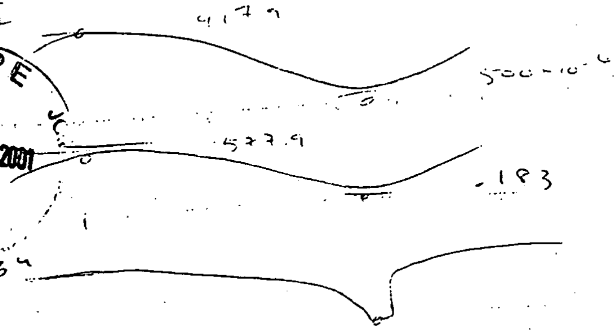
Dated: 10/2/01

Erik R. Thoen

20316552.doc

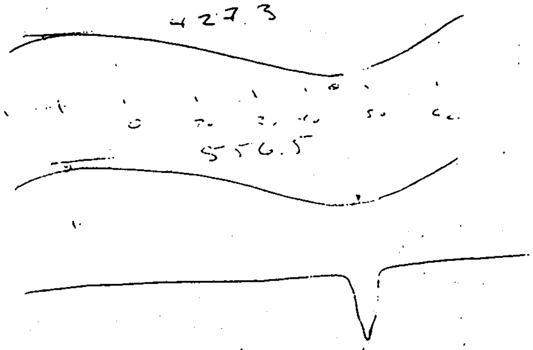
The locking seen [redacted] soliton-like pattern of [redacted]ngle chopping.

SBR III



SBR 980409 07.sh-

42.5%



SBR980409 0f.sh-

60
427

SBR980409 0f.sh-

Blocked

Now calculate the energy density in the fiber laser for a 100 fs pulse, f: 100MHz, $d = 10\times10^{-6}\,\mu m \left(\frac{100\,cm}{m}\right) = 1\times10^{-3}$ cm.

$P_{av} = 100$ mW

$$E_p = \frac{P_{av}}{f}\,\frac{1}{\pi\left(\frac{d}{2}\right)^2} = \frac{100\,mW}{100\times10^{6}\,1/s}\,\frac{1}{\pi\left(\frac{1\times10^{-3}\,cm}{2}\right)^2}$$

$$= 1.273\,\frac{mJ}{cm^2}\,\frac{1000\,\mu J}{mJ} = 1273\,\frac{\mu J}{cm^2}$$

=

REDACTED

From SBR 980403020pfj data set

$\Delta R = 0.08$ at $E_p = 7750\ \mu J/cm^2 = 7.75\ \frac{mJ}{cm^2}$

$$I_{peak} = \frac{7.75\ mJ/cm^2}{150\times10^{-15}\ s}\ \frac{J}{1000\ mJ} = 5.17\times10^{10}\ W/cm^2$$

Now

$$\alpha = \beta\, I_{peak} \qquad \beta = 45\ \frac{cm}{GW} \qquad \text{InP InGaAsP @ 1540}$$

$$\alpha = \frac{45\ cm}{1\times10^{9}\ W}\ 5.17\times10^{10}\ W/cm^2 = 2.33\times10^{3}\ cm^{-1}$$

Now for

$$d = \frac{\lambda}{2} = \frac{1.5}{2} = 0.75\times10^{-6}\ m.$$

but it's really the effective thickness

$$\frac{d}{n} = \frac{0.75\times10^{-6}\ m}{3.167} = 0.237\times10^{-6}\ m\ \frac{100\ cm}{m}$$

$$= 2.37\times10^{-5}\ cm.$$

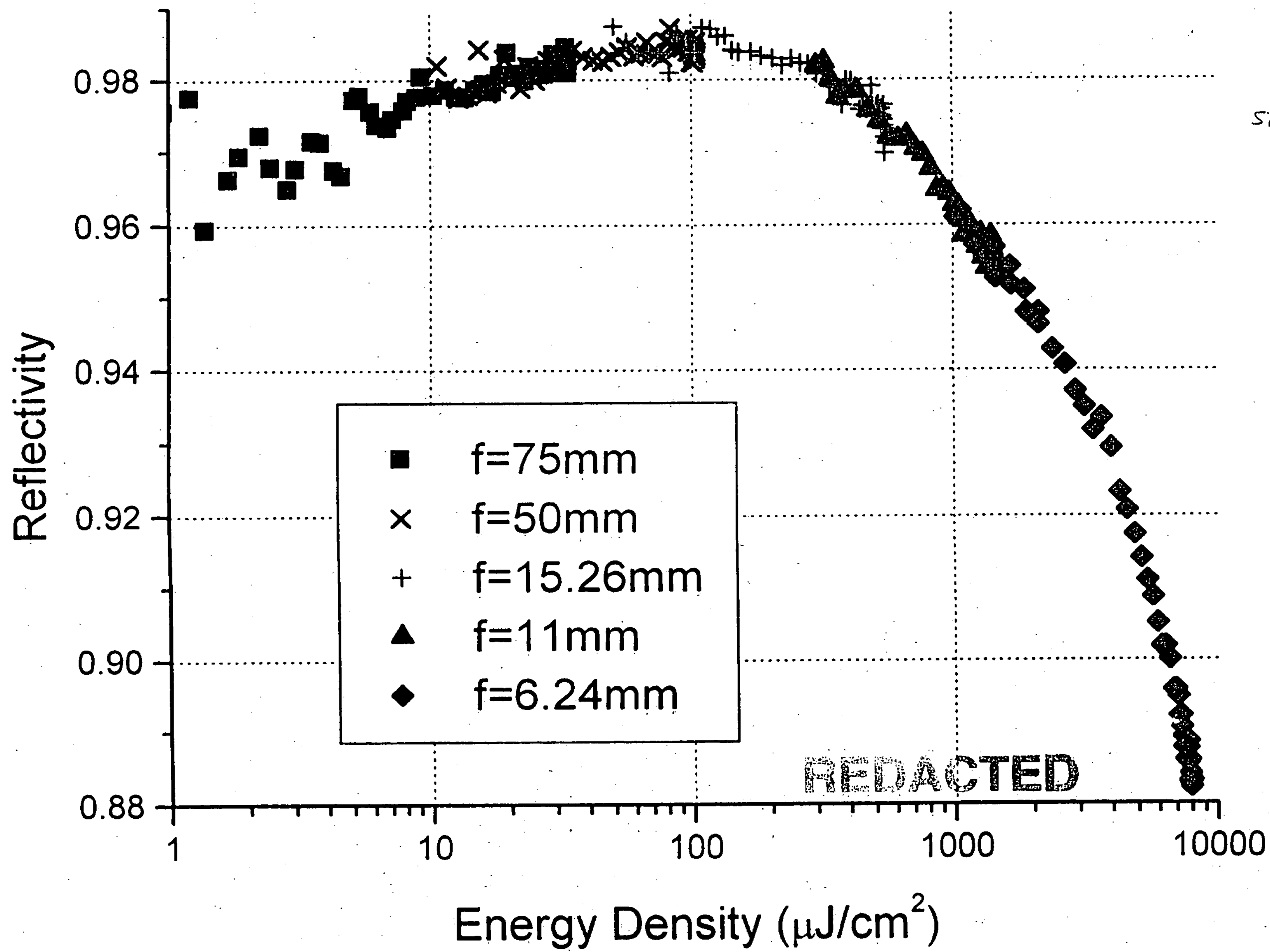
So

$$\text{loss} = e^{-\alpha L} = e^{-(2.33\times10^{3}\ cm^{-1})(2.37\times10^{-5}\ cm)}$$

$$\Delta R = .95$$

I don't consider reflection ⇒ 2nd pass,

so actually much lower ~1.5-2


0.98
0.96
0.94
0.92
0.90
0.88
Reflectivity
1
10
100
1000
10000
Energy Density (μJ/cm²)
f=75mm
f=50mm
f=15.26mm
f=11mm
f=6.24mm
REDACTED

5BRII AR

Active Harmonic Mode-locking of a Linear Fiber Laser Assisted by a Semiconductor Saturable Absorber Mirror

Erik R. Thoen, Matthew E. Grein, Elisabeth M. Koontz,
Leslie A. Kolodziejski, and Erich P. Ippen

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A linear fiber laser cavity is harmonically mode-locked at GHz repetition rates with a traveling-wave phase modulator. The linear cavity geometry facilitates the use of a nonlinear semiconductor mirror. Effects of such a mirror on supermode suppression and pulse shortening have been investigated experimentally.

Submitted to OSA Annual Meeting

Oral presentation preferred
Division: Quantum Electronics
Symposium: Ultrafast Optics in Communications

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